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ABSTRACT

Presented is a summary of the 1977-80 Project LEO studies, which focused on science teaching strategies and learning outcomes for disruptive elementary school children and on more refined application of the "student-structured learning in science" (SSLS) teacher behavioral pattern in secondary school science classrooms. Included within the results are findings that students studying science under SSLS conditions exhibit higher levels of problem solving ability, problem solving confidence, self-initiativeness, self-directiveness, verbal creativity, and positive attitude toward science and toward independent learning. In contrast, "teacher-structured learning in science" (TSLS) students exhibited higher levels of attention to the teacher, imitation of the teacher, copying other students, initiating interaction with the teacher, and disruptiveness. These findings and others are discussed, and implications for science education are explored. (CS)

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PROJECT LEO STUDIES

of

SCIENCE LEARNING ENVIRONMENTS AND OUTCOMES

1968-1981

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by

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Research reported in this paper was done during 1968-1981 as a part of Project LEO, a research cooperative at FSU studying learning environments and outcomes.

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Introduction

Since the 1968 beginning of the Project LEO research cooperative, about fifty investigators from a dozen countries have participated in Project LEO investigations of science learning environments and outcomes at elementary, secondary, and college levels. Specific findings of these separate investigations have been published in several books (1, 2) and periodicals (3-8). Reports of Project LEO studies have been included in presentations to 1973-80 annual meetings of the National Association for Research in Science Teaching (9-16), to the 1977 World Conference of the International Association for the Advancement of Educational Research in Belgium (17), and to 1977 and 1980 triennial world conferences on education sponsored by the World Council for Curriculum

and Instruction in Turkey (18) and the Philippines (19). These papers and others (20-24) are available to persons interested in more specific information than is provided in this present summary.

This paper has two major purposes. The first is to present the most important structures, or organizational frameworks, growing out of and subsequently influencing various aspects of the 1968-81 Project LEO studies. The second is to present a brief up-dated summary of findings on more than 1,000 subjects during this 13-year period.

Structures

Science Teaching as an Art and a Science:

Teaching and research experiences of Project LEO investigators during the last thirteen years have led us to infer fundamental relationships between teaching strategies employed by teachers and their perceptions of long-term goals for their science programs, the characteristics of students enrolled in the programs, the specific short-term objectives for lessons (or "units") of the programs, the strategies to be utilized for assessment of students and of the programs, the mechanisms to be employed for the continuing modification of the programs, and the procedures for "marketing" the programs--or of persuading others that the programs are of value. Teaching strategies seem to be stable and effective to the extent that these seven components are understood by the teacher and are related to each other in mutually supportive ways.

Associating "performance" of science teaching with an "art of science teaching," we perceive careful and comprehensive consideration of these seven components to constitute a "science of science teaching," which supports this performance. The teacher who has internalized the relationships among these seven components in terms of a relevant knowledge (or research) base will perform science teaching in an aesthetically pleasing, artistic fashion. This performance will be comfortable for both teacher and student. One of the structures which grew out of and has influenced Project LEO studies is represented in the "Seven Components of a Science of Science Teaching" given in Attachment One. This "science of science teaching" supports and assures the effectiveness of an "art of science teaching."

Teaching Strategies in Terms of Materials and Behaviors:

What the teacher does (teacher behaviors) and what the teacher uses (materials) are viewed by Project LEO investigators as critical aspects of "teaching strategy." In order to adequately describe and analyze existing practices observed in science classrooms and in order to construct teaching strategies which would be more stable than existing practices (and, therefore, more amenable to study over an extended period), we thought of science teacher behaviors as either "tending to increase alternatives for student learning activities" or "tending to decrease alternatives for student learning activities." We also viewed this same teacher interaction with students as either "tending to seek understanding

of the student's verbal or non-verbal activity" or "tending to judge the student's activity." The four possibilities generated by this pair of dichotomies are shown in Attachment Two as the vertical "columns" in the four-by-four matrix.

As we attempted to understand the science teacher's use of teaching materials in the classroom, it appeared to us that the teacher intended either that materials would be perceived by students as already having been assigned a representational identity or as being "open to assignment" by each student. This produced the two categories "representation assigned" and "representation open" shown in Attachment Two. Furthermore, it appeared that materials were either "manipulated" by the student or merely "observed" by the student.

Attachment Two, "Teaching Strategies in Terms of Patterns of Teacher Behavior and Types of Teaching Materials," presents sixteen contrasting possibilities for "teaching strategy"--each represented by one cell in the four-by-four matrix. To take an example, "Cell 1" represents a teaching strategy in which the teacher interacts with students in such a way as to emphasize the teacher's desire to produce a variety of optional learning activity alternatives for students and to understand the student's perspective on activities in which students are engaged. Materials utilized by this teacher are manipulated by the students and are presented as "open" with regard to representational identity. For example, a styrofoam ball is not identified by the teacher as an atom or a planet. It is, rather, whatever the student decides to "let" it be (represent); its representational identity is "open" to the student.

In contrast, the teaching strategy associated with "Cell 12" would

have the teacher interacting with students in such a way as to emphasize a desire to have each student engage in the specific activities which the teacher considers most appropriate at the moment. That is, the teacher takes action intended to reduce the number of learning activity alternatives to the one (or few) considered best. Also, the teacher tells students what the manipulative materials are (represent). Furthermore, the teacher seeks to judge the work (or learning) of students and, in so doing, communicates whether students are right or wrong--whether they are doing good work or otherwise.

Categories of Teacher Behavior:

Attachment Three is a listing of categories of teacher behavior which were devised for the purpose of analyzing existing practices and also to provide for quantitative descriptions of teacher behavioral patterns to be used as "treatment" in experimental studies. These categories have been described in detail in earlier publications (2). The teacher's behavior is coded at every change in behavior or at the end of three seconds--whichever comes first. "Cell 1" and "Cell 12" teacher behavioral patterns, for which quantitative parameters are given in Attachment Three, have been referred to in earlier publications as "Student-Structured Learning in Science" (SSLS) and "Teacher-Structured Learning in Science" (TSLS) teacher behavioral patterns.

SSLS teacher behavioral patterns are "alternative increasing" and "seeking to understand," while TSLS teacher behavioral patterns are "alternative decreasing" and "seeking to judge." In terms of Table Two, SSLS includes Cells 1, 5, 9, and 13; TSLS includes Cells 4, 8, 12, and

16. In terms of the SCAS categories of teacher behavior given in Table Three, "alternative increasing" patterns of teacher behavior maximizes the importance of category 8 and minimizes the importance of category 9. "Alternative decreasing" is reflected in the use of category 9 as a preference over category 8. "Seeking to understand" involves use of category 3 in preference to categories 4 and 5. Both "seeking to judge" and "seeking to understand" involve the use of categories 2 and 7 (but for different purposes). The negativity of category 5 is avoided in both.

Project LEO experimental studies have used SSLS teacher behavioral patterns with materials which are available for manipulation by students and for which the representational identity is open to students. This "Cell 1" teaching strategy has been compared to "Cell 12," which is the TSLS pattern of teacher behavior with materials which are to be manipulated by students and which have been assigned representational identity by the teacher.

For purposes of Project LEO experimental studies, cell 1 and cell 12 treatments have utilized precisely the same materials. Studies have controlled for time-of-day, student characteristics, teacher characteristics, classroom physical characteristics, etc. Project LEO treatment teaching strategies have been considered achieved when the parameters given in Attachment Three are maintained consistently and when students exhibited no more than ten percent "non-lesson-related" behavior. Both of these treatment teaching strategies are "individualized" in that no more than one percent of the teacher's interaction was with more than six students, even though class size was 25 to 30 students.

Types of Learning Activities:

Beyond consideration of "types of materials" and "patterns of teacher behavior," the Project LEO concept of teaching strategy takes into account five different "types of learning activities." Attachment Four describes these in terms of the "Cell 1" and Cell 12" teaching strategies identified above. These "Types of Learning Activities" are viewed as covering the possibilities for science teaching from kindergarten to graduate school for "Cell 1" and "Cell 12" teaching strategies.

Types of Long-Range Goal Priorities:

Attachment Five depicts a recent "organizational framework" for Project LEO investigations. Preliminary examination of findings indicate that few teachers can generate teaching strategies which are consistent with their own goal orientations or the goal orientations of their students. Furthermore, there appears to be little communication between teacher and student regarding goal orientation.

Attachment Five includes more-or-less parallel statements in three types of priorities associated with long-range goals for science teaching. Goal priorities identified as "A - Information Acquisition Priority" translate roughly into the student's language as, "The main purpose of studying science is to learn facts and information selected by the teacher and the textbook. The "B - Skill Learning Priority" goal statements seem to mean to students: "The main purpose of studying science is to

learn correct ways to do problems and experiments selected and explained by the teacher and the textbook." These seem to represent quite different goal orientations and might be associated with "Cell 16" and "Cell 12" teaching strategies respectively.

The goal priorities identified in Attachment Five as "C - Conceptual Learning Priority" are expressed by students as, "The main purpose of studying science is to learn to understand and use science problems, experiments, and information which I select and decide how to use." This type of priotity in long-term goals seems to be associated with "Cell 1" teaching strategies.

Findings Consistent with Project LEO Studies

Completed Project LEO Studies:

Prior to 1980, Project LEO investigations involved experimental studies comparing the "Cell 1" strategy to the "Cell 12" strategy and one study which compared two variations within the "Cell 1" strategy. These studies have been conducted in elementary, middle school, high school, and college science classrooms. In the various investigations, students were studied in terms of behavioral patterns, problem-solving ability and confidence, over-all confidence level, cognitive developmental characteristics, self perceptions with regard to science and independent activity, information acquisition, predictability of student behavioral pattern, achievement motivation, affiliation motivation, locus of control, anxiety level, critical thinking ability, creativity, and other indicators

of learning environments and outcomes. Students "subjected" to "cell 1" and "cell 12", as treatment teaching strategies, were compared in terms of sex, ethnicity, cognitive developmental level, school achievement, etc. One cell 1/cell 12 study involved student subjects identified for their extreme disruptive tendencies.

Details of these studies may be found in earlier reports (1, 2, 4 - 22). The following statements are indicative of some of the major findings of studies completed during the last thirteen years.

1. Compared to "Cell 12" students, "Cell 1" students exhibited higher levels of:
   a. ability to solve problems,
   b. confidence in their ability to solve problems,
   c. figural creativity,
   d. self-initiative, self-directiveness, and behavioral pattern predictability in engaging in learning activities, and
   e. student-to-student interaction on lesson-related matters.
2. Compared to "Cell 1" students, "Cell 12" students exhibited higher levels of:
   a. listening to and watching the teacher,
   b. carrying out teacher designated activities,
   c. copying other students,
   d. initiating interaction with the teacher, and
   e. dependency on the teacher.

3. In general, "Cell 1" and "Cell 12" students exhibited about the same levels of:
   a. information acquisition,
   b. achievement motivation, and
   c. cognitive development.
4. Using the California Short-Form Test of Mental Maturity and previous achievement grades, students were privately designated as low-, middle-, and high-achieving. Data revealed that:
   a. "Cell 1" low- and middle-achieving students did as well as "Cell 1" high-achieving students in problem solving,
   b. "Cell 12" high-achieving students did about the same as "Cell 1" high-achieving students in problem solving,
   c. "Cell 12 low-achieving students did not do as well as "Cell 12" middle-achieving students and "Cell 12" middle-achieving students scored lower than "Cell 12" high-achieving students on problem solving,
   d. "Cell 12" low-achieving students exhibited less "lesson-related" behavior than other "Cell 12" students while "Cell 1" low-achieving students exhibited about the same level of "lesson-related" behavior as other "Cell 1" students, and
   e. "Cell 12" low-achieving students observed the teacher more than other "Cell 12" students but followed teacher directions less--while this difference was not observed among the "Cell 1" low-, middle-, and high-achieving students.
5. When ethnicity and sex differences were studied, it was found

that:

a. black male "Cell 1" students out-performed all other groups ("Cell 1" white and black females, "Cell 1" white males, and "Cell 12" white and black males and females) on problem solving while black male "Cell 12" students showed the lowest performance on problem solving; and

b. black female "Cell 1" students performed better on problem solving than black female "Cell 12" students."

6. In studies of students who had been designated for the three previous years as "disruptive," it was found that:

a. the level of disruptiveness under "Cell 12" conditions was so great (in a class size of 12 students) as to prevent behavioral data collection and to require termination of lessons while no such problems developed under "Cell 1" conditions; (This required reduction of class size for "Cell 12" treatment from 12 to 6 students; in order to maintain parallel conditions, this reduction was also made for "Cell 1);

b. the level of disruptiveness (although higher under "Cell 12" than "Cell 1") was not significantly different in class sizes of 6 students; and

c. "Cell 12" and "Cell 1" "disruptive" students showed the same variations reported in 1c, 1d, 2a, 2b, 2c, 2d, and 2e above.

7. In general, "Cell 1" and "Cell 12" students differed in behaviors as indicated in Attachment Six.

8. In studies of anxiety levels (Taylor Manifest Anxiety Scale) of "Cell 1" and "Cell 12" students, it was found that:
   a. "cell 12" students with higher anxiety levels devoted more time to looking at, listening to, and copying the behaviors of other students;
   b. "cell 1" students with higher anxiety levels devoted less time to giving ideas to other students; and
   c. "cell 12" students with higher anxiety levels devoted less time to lesson-related activities.
9. Within the "Cell 1" treatment strategy, teacher use of affective and higher level (comprehension, application, analysis, synthesis, and evaluation) questions was associated with higher performances on critical thinking and abstract reasoning tests--as compared to students taught by the "Cell 1" strategy in which the teacher used managerial and lower level (knowledge) questions. This was found to be the case for abstract reasoning scores with both students of high grade point averages and students with low GPA's.

Project LEO Studies Not Yet Completed:

In the Spring of 1980, a preliminary study with 10-year-olds to compare the "Cell 1" strategy to the "Cell 16" strategy was initiated. The "outcome" of the study was too obvious to require statistical treatment of data. As has been the case in all Project LEO experimental studies, students within given schools were randomly assigned to treatment

groups and teachers were trained to implement both treatment teaching strategies.

As has been the case in previous studies, students in both treatment groups were able to communicate with each other outside of class. In this case, students assigned to the "Cell 16" treatment group rejected so thoroughly the assignment as to make it impossible within six weeks to reduce non-lesson-related behavior below the Project LEO standard of ten percent. Other aspects of data collection were rendered impossible by the failure of subjects to cooperate. It was apparently the communication between the two treatment groups which produced the strong hostility of the "Cell 16" group. This group insisted that they be given manipulative materials "just like the other group." Otherwise, they continued, "It is not fair for us to have to work in the book and just have demonstrations when the others get to build things and do experiments every day."

Although the services of a professional school counselor helped to reduce the hostility, it was not possible to establish the necessary level of lesson-related behavior nor to collect other data reliably. Clearly, it would be necessary to implement these two treatment teaching strategies with isolated groups of subjects. Of course, this raises serious questions regarding the possibility of randomization of subjects. Meanwhile, this "study" provides the clearest possible information regarding student preferences and attitudes regarding "Cell 1" versus "Cell 16" teaching strategies for these subjects.

A Project LEO study currently under way and scheduled for completion in June, 1981 is designed to analyze existing practices in 18 middle school science classrooms in five middle schools and to establish techniques and instruments for similar analyses at high school and college levels.

Utilizing a variety of observational and one-to-one interview techniques and instruments, the current study is a preliminary examination of middle school science in terms of the following:

1. teachers' and students' perceptions of "goal priorities" for science;
2. teachers' and students' perceptions of classroom behaviors of teachers and of students,
3. teachers' and students' conceptions of ideal behaviors of science teachers and of science students,
4. observed behaviors of science teachers and students, and
5. teachers' and students' expressed preferences for four "modes of functioning" (in terms of Jungian typology utilizing the MBTI instrument).

Preliminary examination of data from 12 teachers and 120 students indicates that "Cell 16" is the almost exclusive teaching strategy. An informal sampling of teacher behavioral data is shown in Attachment Three. This "alternative-decreasing" and "judging" teacher behavioral pattern combined with the almost exclusive use of "representation-assigned" and "to-be-observed only" materials is associated with a student behavioral pattern given in Attachment Six (from preliminary examination of student behavioral data).

A second Project LEO study currently under way looks at college level students in terms of their cognitive developmental levels (Piaget), their preferences for four modes of functioning (Jungian typology via the MBTI), their electroencephalographic (brain wave) coherence, their levels of science reasoning ability, and their achievement levels (grades) in college and high school science courses.

Summary and Selected Implications

In summary of these 1968-81 Project LEO studies, it might be said that findings have consistently indicated that students studying science in a "Cell 1" environment exhibited higher levels of problem solving ability, problem solving confidence, self-initiative, self-directiveness, figural creativity, and positive attitude toward independent learning. "Cell 12" students exhibited higher levels of attention to the teacher, imitation of the teacher, copying of other students, initiating interaction with the teacher, and disruptiveness. Information acquisition seemed to be about the same for "Cell 1" and "Cell 12" students.

Although Project LEO findings suggest to some that all students are more independent and fully functioning under "Cell 1" than under "Cell 12" conditions, there are indications that certain specific sub-groups of students are more severely deprived under "Cell 12" conditions than other sub-groups of students. For example, black male students, low-achieving students, and (to a lesser extent) black female students, are less able to solve problems if taught science in a "Cell 12" environment.

It appears that educators who wish to enhance creativity, problem solving ability, problem solving confidence, student initiative, student self-directiveness, positive attitude toward independent study and what might be called holistic learning should take the necessary training to be able to implement a consistent Project LEO "Cell 1" strategy. Educators who wish to make learning equally available to different ethnic groups of both sexes and equally available to low-achieving and high-achieving students (without disadvantage to any students) should learn the "Cell 1" teaching strategy. Science educators who reflect a different set of

values in their goal priorities might well learn and use a "Cell 12" strategy--or one of the other strategies reflected in Attachment Two.

These findings seem consistent with results found in a great variety of independent studies. Educators such as Carl Rogers (25) and Jerome Kagan (26) have independently observed that human beings exhibit a natural tendency toward learning. Bruner's group (27), the Piagetian school (28) and certain of the Soviet psychologists (29) are in agreement on the conceptualization of natural (spontaneous) cognitive growth as the development of increasingly powerful representation systems for dealing with future encounters of the organism with reality. Independent studies of teaching by Smith (30), Anderson (31), Flanders (32) and many others have consistently indicated that the most effective educational environments are those which are structured so that the openness allows each student to select learning activities and goals compatible with his/her own preferences. Rogers (25) indicated that "long-term learning" was characterized by "personal involvement, self-initiation, a sense of discovery, pervasiveness, self-evaluation, and meaningfulness."

One of the aspects of Project LEO studies which is not revealed in the published findings, but which is obvious to the investigators, is related to the apparent inability to teachers to maintain the "Cell 1" environment outside the research setting. Among teachers at all levels, there seems to exist a malaise, a nervousness, or an uncertainty which seems to produce a "leaf-in-the-wind" approach to teaching--an approach inconsistent with the conscious establishment of any stable teaching strategy.

Many teachers express a fear of establishing the "Cell 1" conditions. Others who express the desire to establish these conditions frequently are not in a position to "take the heat" associated with something "new." Teachers who have been able and willing to establish the "Cell

1" conditions are frequently unable to maintain the conditions with the consistency required for success. The few teachers who have been able to establish and maintain the "Cell 1" conditions seemed to face the insecurity of administrators, the inflexibility of parents, and the newly-acquired blunt honesty of students. These teachers become aware of serious cognitive and emotional difficulties in their students and find it difficult to cope with this new awareness. Consequently, the "Cell 1" environment seldom survives outside the research environment. The "best" "Cell 1" teachers gradually become very pleasant "Cell 12" teachers. "Cell 16" seems to have retained its position of clear dominance.

Several studies seem consistent with these subjective "findings" and the current investigations of Project LEO. For example, after visiting hundreds of schools and trying to see what was happening as a result of extensive U. S. school reforms, Charles Silberman wrote in Crisis in the Classroom (33):

> The great bulk of students' time is still devoted to detail, most of it trivial, much of it unrelated to any concept, structure, cognitive strategy, or indeed anything other than the lesson plan.

John Goodlad (34) commented after a similar study: ". . . we are forced to conclude that much of the so-called educational reform movement has been blunted on the classroom door."

A 1974 report (35) indicated that 700,000 U. S. children under 17 years of age were suffering from learning disabilities and three million were either mentally retarded or emotionally disturbed. Regarding British students the following was published (36):

> ". . . at fifteen (years of age) not less than one in five had either handicaps, recurrent illness, intellectual limitation, poor education performance or severe difficulties of emotional or social

adaptation. This residual disability is a true measure of our failure to deal effectively with the physical and educational disorders of children . . ."

In 1971, Instructor magazine (37) asked its readers in the United States the question: "Is teaching hazardous to your health?" More than four-fifths of the 7,000 respondents answered affirmatively and cited "stress" as their biggest health problem. They indicated that the stress manifested itself in "headaches, hypertension, and nervous stomach." Ninety-six percent reported their health to be excellent during the summer vacation period.

Hans Selye's (38) discovery of stress, the body's nonspecific response to all demands made upon it, has significantly increased the medical understanding of how chronic tension accumulates in people through repeated exposure to demanding circumstances. Though the body can spontaneously adapt to excessively demanding circumstances, these responses tax body resources tremendously and reduce the body's subsequent capability for restoring psychophysiological equilibrium. If the body does not completely restore vital bodily resources and reduce hormones which sustain hyperarousal, stress becomes excessive and destroys mental and physical well being. The resulting tension brings on poor health, chronic dissatisfaction, and the tragic absence of coherence and stability of functioning.

Psychologist Maynard Shelly (39) has speculated that the chronic stress of modern life leads to a gradual increase in our optimum arousal level. This places ever-increasing demands on already-stressed teachers to "motivate" students, or arouse their interest. These teachers seem to keep trying in vain to make the "Cell 16" strategy "work."

It seems clear that more long-range research is needed. It also seems clear that "government-supported" research has not (and will not soon) fill the need for this long-range research. Perhaps the cooperative "model" of Project LEO offers a possibility of re-establishing the integrity of the researcher and bringing his/her attention and energies to doing (rather than merely proposing) research in Science Education.

Even so, it seems likely that merely increasing the research base for science education will not change the ability of science teachers and administrators to understand and apply these findings. Undergraduate and graduate study in science education might well become more scientific and "investigation" oriented. Science teachers might well learn to learn science teaching by studying science teaching and learning. Science Educators in teacher preparation might consider reducing the level of dogmaticism involved in the preparation of science teachers and researchers in undergraduate and graduate courses and programs. Science Education might well be improved by a higher level of scientific skepticism--a skepticism which <u>examines</u> rather than dismisses or pronounces with arrogance, fear, complacency, or laziness. Science education might well <u>consider</u> (with scientific skepticism) the possibilities for teaching science and for educating science teachers and more forceful ways of bringing possibilities to the attention of teachers, administrators, parents, and government officials.

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Attachment One

SEVEN COMPONENTS OF A SCIENCE OF SCIENCE TEACHING

(This "Science of Science Teaching" is viewed as supporting an "Art of Science Teaching," considered to be the performance phase of science teaching).

1. Holistic Goals

   a. Values
   b. Intentions
   c. Motivations

2. Characteristics of Learners

   a. Cognitive
   b. Affective
   c. Psychomotor

3. Specific Objectives

   a. Cognitive
   b. Affective
   c. Psychomotor

4. Teaching Strategies

   a. Patterns of Teacher Behaviors
   b. Types of Teaching Materials
   c. Types of Learning Activities
   d. Content

5. Marketing Strategies

   a. For Administrators and Supervisors
   b. For Parents and the General Public
   c. For Potential Students

6. Assessment Strategies

   a. For Program
      (1) Existing Research Findings
      (2) Design of Research to be Done
   b. For Students
   c. For Teachers

7. Modification Strategies

   a. For Program
   b. For Students
   c. For Teachers
   d. For School Administrators
   e. For School Organizational Structure

Attachment Two

Types of Teaching Strategies in Terms of Patterns of Teacher Behaviors and Types of Teaching Materials*

Types of Teaching Materials			Patterns of Teacher Behavior**			
			Alternative Increasing		Alternative Decreasing	
			Seeking to Understand	Seeking to Judge	Seeking to Understand	Seeking to Judge
Representation Open		To be Manipulated	1	2	3	4
		To be Observed	5	6	7	8
Representation Assigned		To be Manipulated	9	10	11	12
		To be Observed	13	14	15	16

*Types of Teaching Strategies are also defined in Project LEO in terms of "Types of Learning Activities" and "Content."

**Patterns of Teacher Behavior are defined quantitatively in terms of the Science Curriculum Assessment System categories of teacher behavior.

Attachment Three

SCAS Teacher Behavior* Ranges for Cells 1, 12, and 16

Verbal and Nonverbal Teacher Behaviors	Cell 1	Cell 12	Cell 16	
1. does not observe student behavior	0-1%	0-1%	0-55%	8% average
2. observes student behavior without response	40-60%	20-40%	7-65%	36% average
3. accepts (without judging) student behavior	10-20%	1-2%	0-10%	4% average
4. judges student behavior positively	0-2%	10-20%	0-12%	3% average
5. judges student behavior negatively	0-2%	0-20%	0-13%	5% average
6. threatens or ridicules student	0%	0%	0-1%	0% average
7. asks question which does not tell student what to do or how to do an activity	20-40%	15-30%	0-23%	7% average
8. gives information which does not tell student what to do or how to do an activity	1-5%	1-5%	0-67%	10% average
9. makes statement or asks question which tells student what to do or how to do an activity	0-2%	20-40%	2-82%	28% average

*SCAS teacher behavior categories also distinguish between teacher interaction with 1-6 students ("S") and teacher interaction with 7 or more students ("T"). By design, less than 1% of "Cell 1" and "Cell 12" teacher behaviors were "T" behaviors in Project LEO experimental studies. "Cell 16" data given above is preliminary and results from informal examination of findings in a study of existing practices in twelve middle school science classrooms. More than half of these "Cell 16" teacher behaviors were "T" behaviors.

Attachment Four

Types of Learning Activities for Project LEO Cells 1 and 12

Activity Type	Cell 1	Cell 12
One	Students use self-selected sets of non-representational materials (which are usually provided by the teacher) for the creation of structures and patterns and for fantasy and game-playing. Students (at any cognitive level) who have had limited experience with independent investigation usually engage in Type One Activities. Students at the pre-operational level of cognition (whether experienced or not) usually engage in Type One Activities.	Students use materials (as directed by teacher) for engaging in the identification and measurement of specific predetermined properties of objects. In addition to observing and measuring, students use materials for classifying, counting, pretending, and stating their findings. When the teacher considers it appropriate, the child moves to Type Two Activity.
Two	Students use self-selected sets of non-representational materials for seeking relationships among the properties of objects. Without pressure to get "correct" relationships students are given opportunities to identify and make statements of relationships in any way they choose. Much variation from one student to another is observed and accepted. Inexperienced students at the formal operational level usually choose this type of activity after some experience in Type One Activity. Both experienced and inexperienced students at the concrete operational level usually choose this type of activity—again after some experience in Type One Activity.	Students use materials (as directed by the teacher) for making predictions and pictorial representations and for identifying specific predetermined relationships among the properties of the objects. When the teacher considers it appropriate, the student moves back to Type One Activity or on to Type Three Activity.
Three	Students use self-selected, nonrepresentational materials for seeking relationships among the various factors associated with the behavior of systems. Students usually make gradual shifts through Type One and Type Two to Type Three Activities as their cognitive development and experience permit. Experienced students at the late concrete operational stage and formal operational stage usually choose Type Three Activity.	Students use materials (as directed by the teacher) for identifying properties of objects and relationships among the factors which influence the behaviors of systems. Students follow instructions on inferring, defining operationally, formulating hypotheses, and interpreting data. Students regress to Type One or Type Two or progress to type Four at the discretion of the teacher.

Activity Type		
Four	Students identify problems, materials and procedures and conduct investigations of their own design. Sets of objects are *not* presented to students by the teacher. Total freedom is given to students in identifying problems which interest them. (Obvious limitations of nonavailability of materials and personal safety are involved.) Students functioning at the formal operational level and experienced in Type Three Activity usually choose Type Four Activity.	With greater emphasis on representational materials, students follow the teacher's directions in the use of materials for identifying and controlling variables, experimenting, and formulating models. Students identify necessary materials for carrying out the teacher's instructions. At the teacher's discretion students usually proceed to Type Five Activity.
Five	Students utilize representational materials in investigating the processes and outcomes of workers in fields of their own interests, usually reading historical and/or current accounts of scientific work. Students who recognize that knowledge is person-made and tentative usually choose Type Five Activity without the displacement of the previous four types of activity. Students read about both success and failure in efforts of scholars and researchers. Type Five Activity is usually selected by widely-experienced students who have reached formal operational cognition and who have a continuing interest in the field of endeavor under study.	Using representational materials, students follow the teacher's directions in using expert sources for the purpose of checking the correctness of their own acquisition of new information and for identifying procedures to use in their investigations. Based primarily on ideas from their readings, students identify materials and procedures for new investigations. With the teacher's approval, they conduct investigations which were not initiated by the teacher. At the teacher's discretion, students return to the previous four types of activity or continue with Type Five Activity.

Attachment Five. Types of Long-Range Goal Priorities

A1.0 Information acquisition is of major importance, and training the student in selected information is top priority in education. Consistent with this, science education has the following goals:

A1.1 It enhances the verbal skills of the student. It provides activities compatible with the acquisition of existing scientific information (established definitions and current conventions) and relevant characteristics of each student.

A1.2 It enhances the student's belief that his/her acquisition of existing scientific information will preserve his/her environment, which is necessary because he/she is a part of it and dependent upon it.

A1.3 It facilitates for each student the development of a positive self-concept with regard to the acquisition of existing scientific information.

A1.4 It facilitates the development of interests, attitudes, and personality attributes which are compatible with the acquisition of existing scientific information.

A1.5 It facilitates the student's tendency to seek accurate and precise statements of existing scientific information which can remain unchanged throughout his/her life.

A2.0 A science program should have objectives associated with both affective and cognitive learning. The cognitive objectives should be associated with training the student to learn and remember existing scientific information (definitions and conventions) and the way in which this existing knowledge has been used to solve problems. The student who completes the science program should be able to state scientific information (definitions and conventions) which requires that he/she:

A2.1 make oral and written statements which identify and give properties for specified objects.

A2.2 make oral and written statements which describe relationships among properties of specified static objects or among the factors which affect behaviors of specified dynamic systems.

A2.3 use only expert sources to derive oral and written statements and to check the correctness of the statements.

A3.0 The affective objectives should be associated with the development of an accurate self-concept with regard to the acquisition of existing scientific information (definitions and conventions). The student who completes the science program will:

A3.1 correctly assess his/her own ability to accurately and precisely state (orally and in writing) existing scientific information relative to those of his/her peers.

A3.2 describe science in terms of existing scientific information.

A3.3 give correct and precise oral and written statements of explanations for natural phenomena which have been explained in his/her science program.

A3.4 identify correct and precise verbal statements as an important characteristic of scientific knowledge.

B1.0 Skill learning is of major importance and training the student in selected skills is the top priority for education. Consistent with this, science education has the following goals:

B1.1 It enhances the verbal and manipulative skills of the student. It provides activities compatible with the structure of science, task analyses of the processes of science, and the characteristics of each student.

B1.2 It enhances the student's belief that his/her careful attention to directions, based on the judgment of authorities, will preserve his/her environment which is necessary because he/she is a part of it and dependent upon it.

B1.3 It facilitates for each student the development of a positive self concept with regard to following directions in the manipulation of his/her environment.

B1.4 It facilitates the development of interests, attitudes, and personality which will fit into the expert's perception of societal needs.

B1.5 It facilitates the student's tendency to seek correct ideas and values which can remain unchanged throughout his/her life.

B2.0 A science program should have objectives associated with both affective and cognitive learning. The cognitive objectives should be associated with training the student in the skills of science and the ways in which these skills are used in solving practical problems. The student who completes the science program should be able to follow instructions which require that he/she:

B2.1 manipulates objects in ways that identify and measure the properties of the objects.

B2.2 identify relationships among properties of static objects or among the factors which affect the behaviors of dynamic systems.

B2.3 use only expert sources to check the correctness of the relationships which he/she has identified.

B3.0 The affective objectives should be associated with the development of an accurate self-concept with regard to skill learning. The student who completes the science program will:

B3.1 correctly assess his/her own science skills relative to those of his/her peers.

B3.2 describe science in terms of overt verbal and manipulative skills.

B3.3 state correct explanations for natural phenomena which he/she has covered in his/her science program.

B3.4 state the correct expanation for an observed phenomenon which has been explained previously to him/her.

B3.5 identify correctness as an important characteristic of scientific knowledge.

C1.0 Conceptual learning is of major importance and facilitating the student's conceptualizations is top priority in education. Consistent with this, science education has the following goals:

C1.1 It enhances the thinking ability of the student. It provides activities compatible with pre-operational, concrete operational, and formal operational thought in the pursuit of investigations of the environment or the solutions of problems.

C1.2 It enhances the student's belief that he can interpret and manipulate his/her own environment, that he/she is a part of his/her environment and dependent upon it.

C1.3 It facilitates for each student the development of a positive self-concept with regard to independent learning and the manipulation of his/her environment.

C1.4 It facilitates individual development of interests, attitudes, personality and creativity which enhance the continued development of individuality in the learner.

C1.5 It facilitates the student's tendency to accept the existence of individuals who have ideas and values which are different from his/her own.

C2.0 A science program should have objectives associated with both affective and cognitive learning. The cognitive objectives should be associated with the goal of communicating what science is and how creative and systematic thinking relates to solving self-perceived problems. The student who completes the science program should be able to design activities (without suggestions) and do activities (without instructions) in which he/she:

C2.1 manipulates objects in ways that are dependent upon the properties of the objects.

C2.2 identifies relationships among the properties of "static objects" or among the factors which affect the behaviors of dynamic systems.

C2.3 manipulates objects to test the usefulness of the relationships which she/he has identified.

C3.0 The affective objectives should be associated with the development of a positive self-concept with regard to independent learning. The student who completes the science program will:

C3.1 identify himself/herself as a person who can be successful in science and who chooses to use science.

C3.2 describe science in terms of activities which make sense to him/her.

C3.3 state <u>his/her own</u> explanations for natural phenomena and should modify these only when they cease to be compatible with <u>his/her own</u> interpretations of his/her environment.

C3.4 frequently state alternative explanations for an observed phenomenon.

C3.5 identify "tentativeness" as an important characteristic of scientific knowledge.

Attachment Six

SCAS Student Behaviors for Cells 1, 12, and 16*

Verbal and Nonverbal Student Behaviors	Cell 1	Cell 12	Cell 16
1. Observes teacher	1-2%	5-10%	0-45% 14% average
2. Does required activity or does optional activity by teacher directions	0-1%	40-60%	3-86% 37% average
3. Does optional activity of his/her own design	40-60%	0-5%	0%
4. Responds to teacher question	1-5%	1-2%	0-7% 0.9% average
5. Initiates interaction with teacher; attempts to interact with teacher; continues self-initiated interaction with teacher	0-2%	5-10%	0-8% 1.4% average
6. Initiates interaction with student; attempts to initiate interaction with student	0-2%	0-2%	0-3% 0.6% average
7. Receives from student	15-25%	5-15%	0-17% 4% average
8. Copies or follows instructions of student who is not acting for the teacher	1-5%	1-10%	0%
9. Gives to student--not at request of teacher	5-10%	5-10%	0-12% 1.7% average
N. Total non-lesson-related behavior	5-10%	5-10%	3-88% 40% average

*SCAS student behavior categories distinguish between lesson-related ("L") behaviors and non-lesson-related ("N") behaviors. All behaviors given above are "L" behaviors--except for those shown as "N" behaviors. Project LEO experimental studies have accepted a treatment teaching strategy as stable only if "N" is less than 10%.